Appendix F
Examples

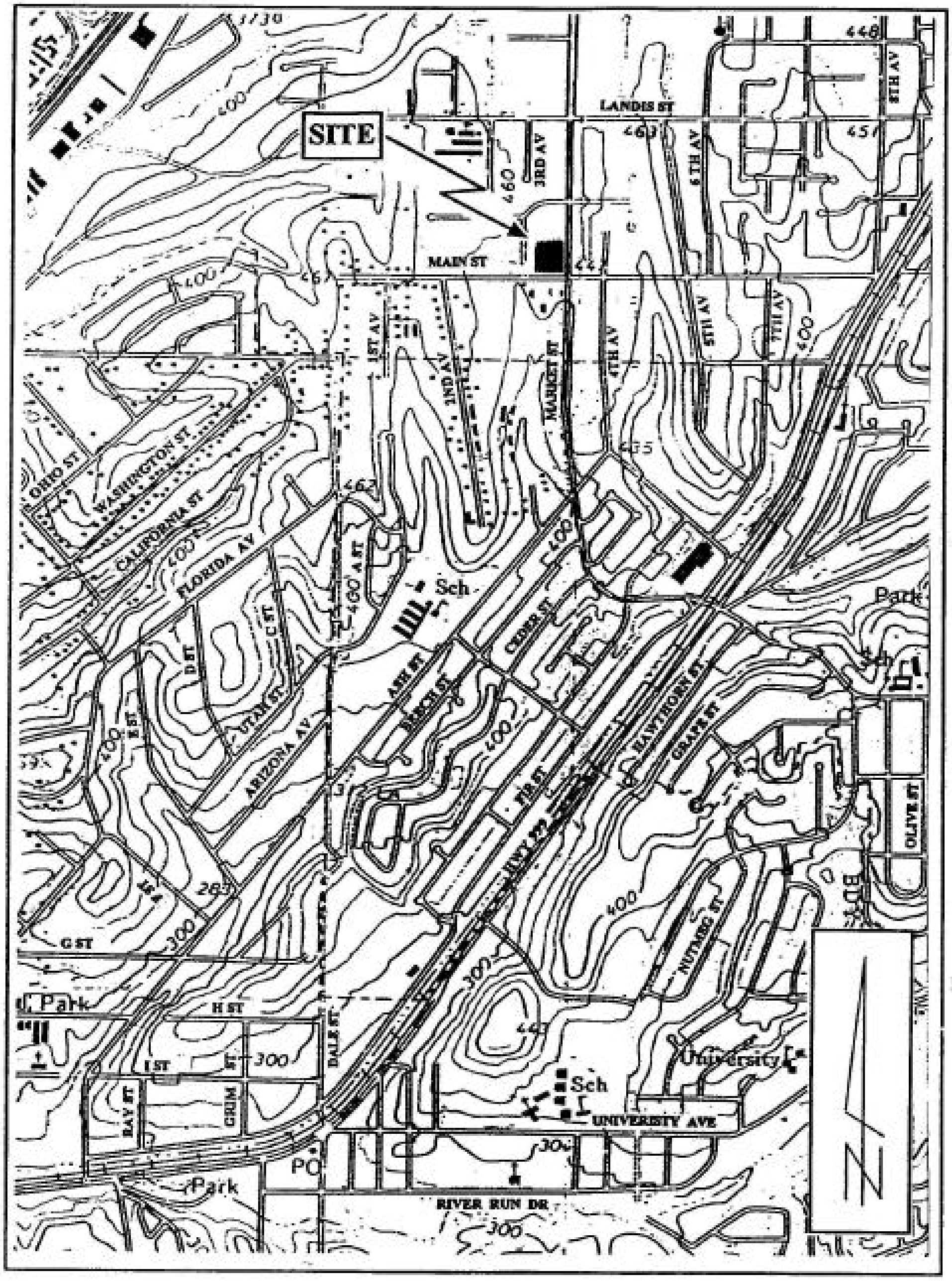
CONTENTS OF APPENDIX F

I. MAPS AND CROSS SECTIONS PRESENTATION OF DATA

All work related to site assessment and mitigation must be documented in a clear and concise manor. In geological and engineering activities, the use of maps and cross sections is a valuable tool in presenting simple-to-very-complex issues.

All site investigations and monitoring reports should incorporate maps and cross sections, including, but not limited to, the following information:

- Site location/vicinity map
- Adjacent land use map
- Utilities site map
- Site map
- Geological cross sections
- Groundwater gradient maps
- Groundwater sampling results map
- All sample locations and relevant sample results



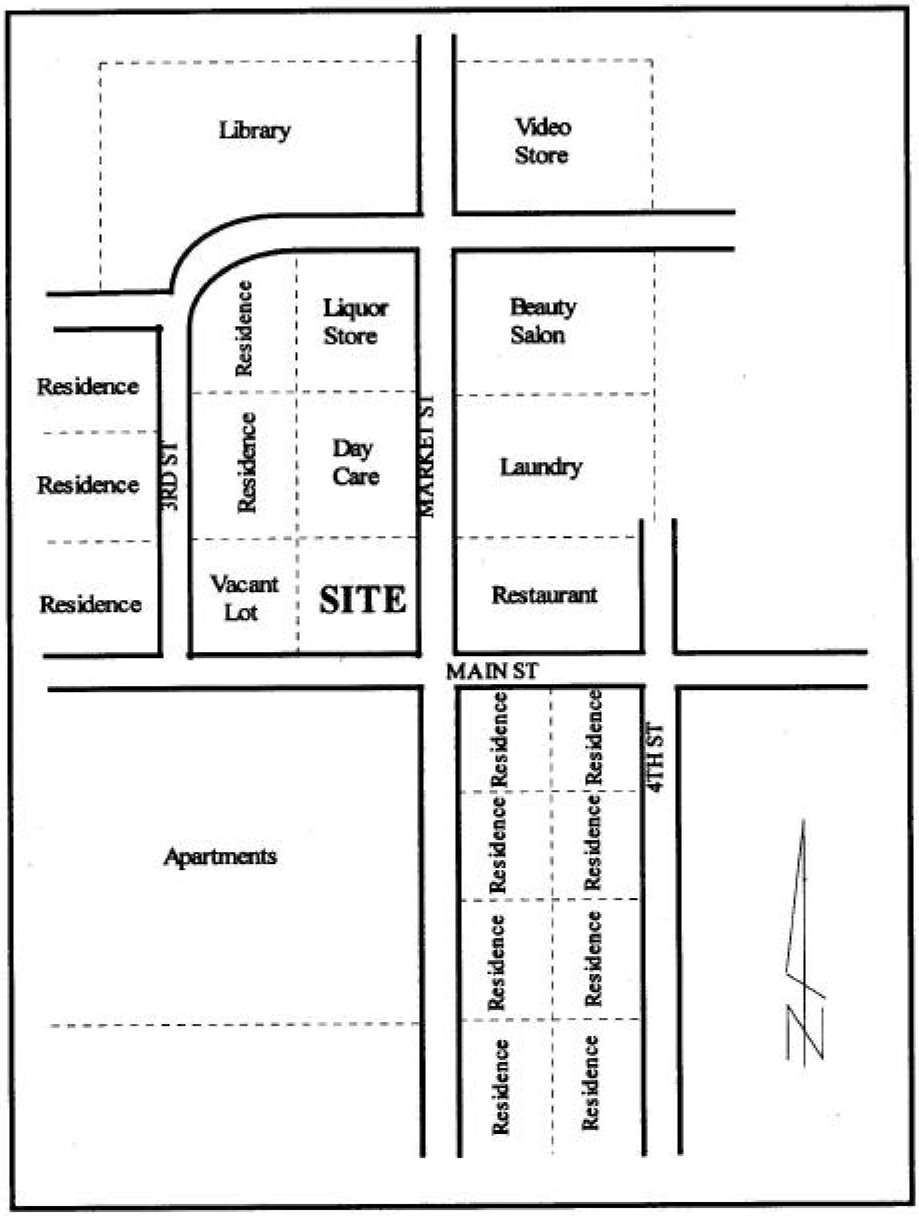
VICINITY MAP

FIGURE 1

Scale (miles)

0 .25 .50

Date: June 4, 1995



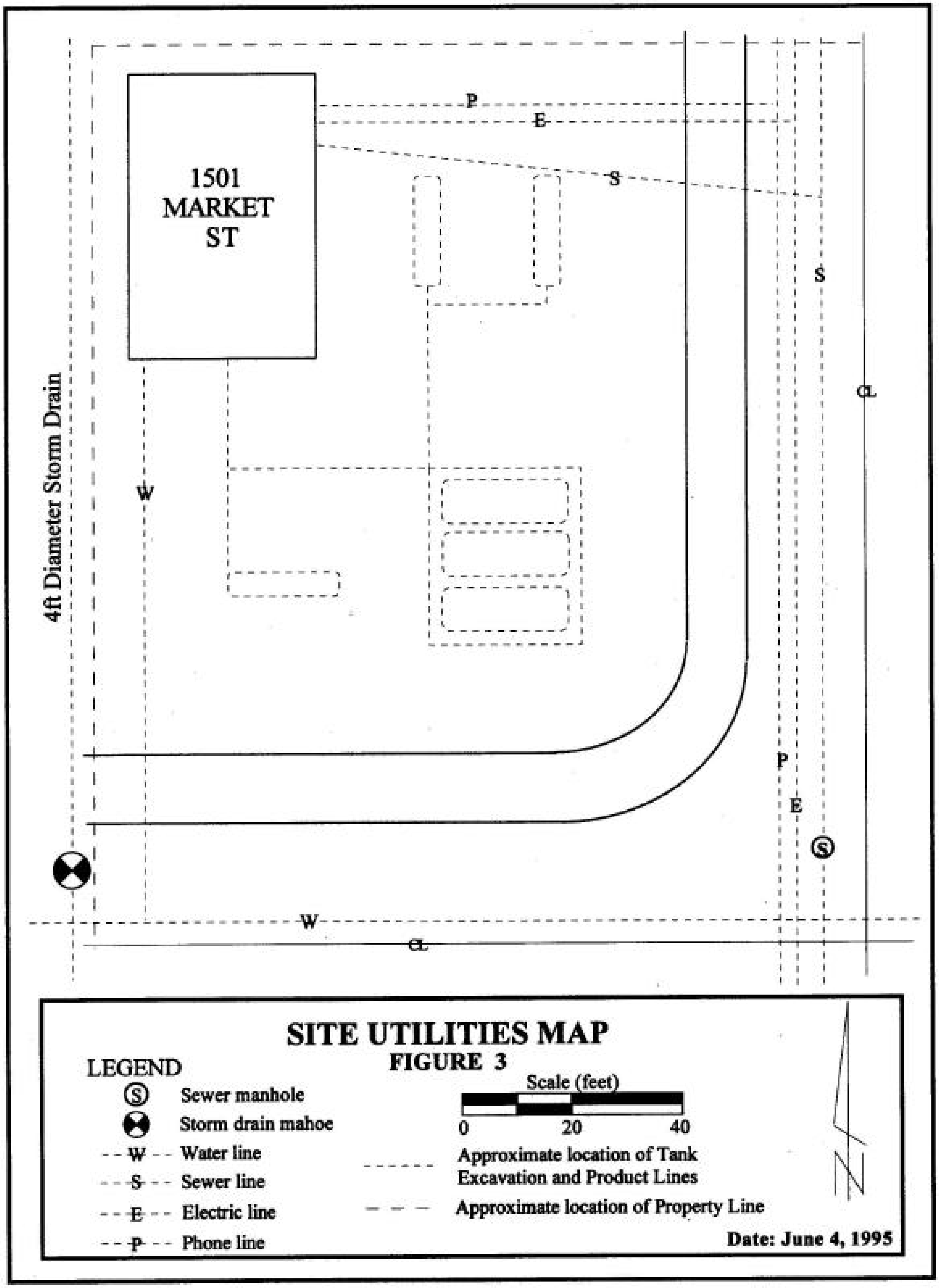
SITE MAP AND SURROUNDING LAND USE

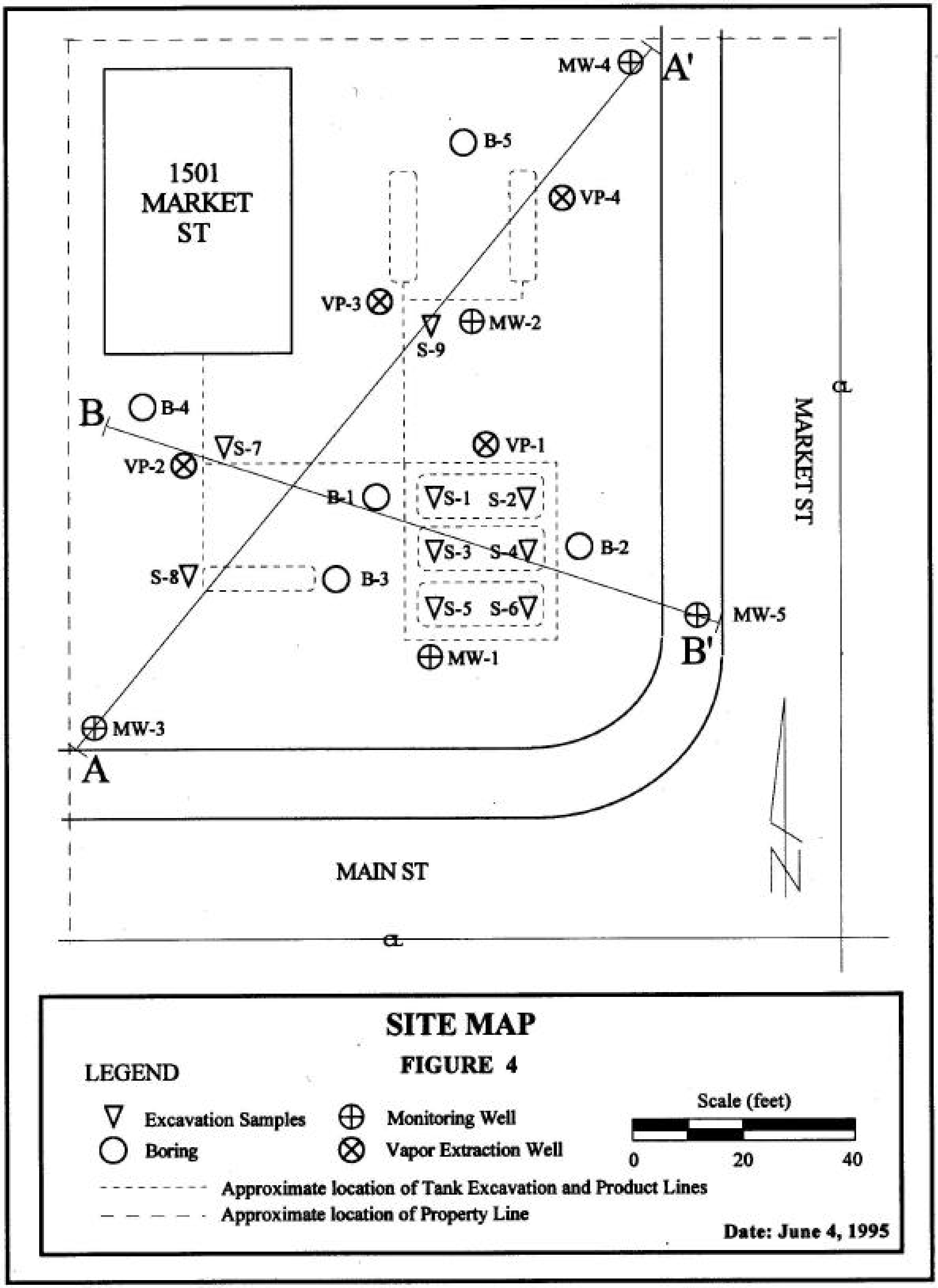
FIGURE 2

Scale (feet)

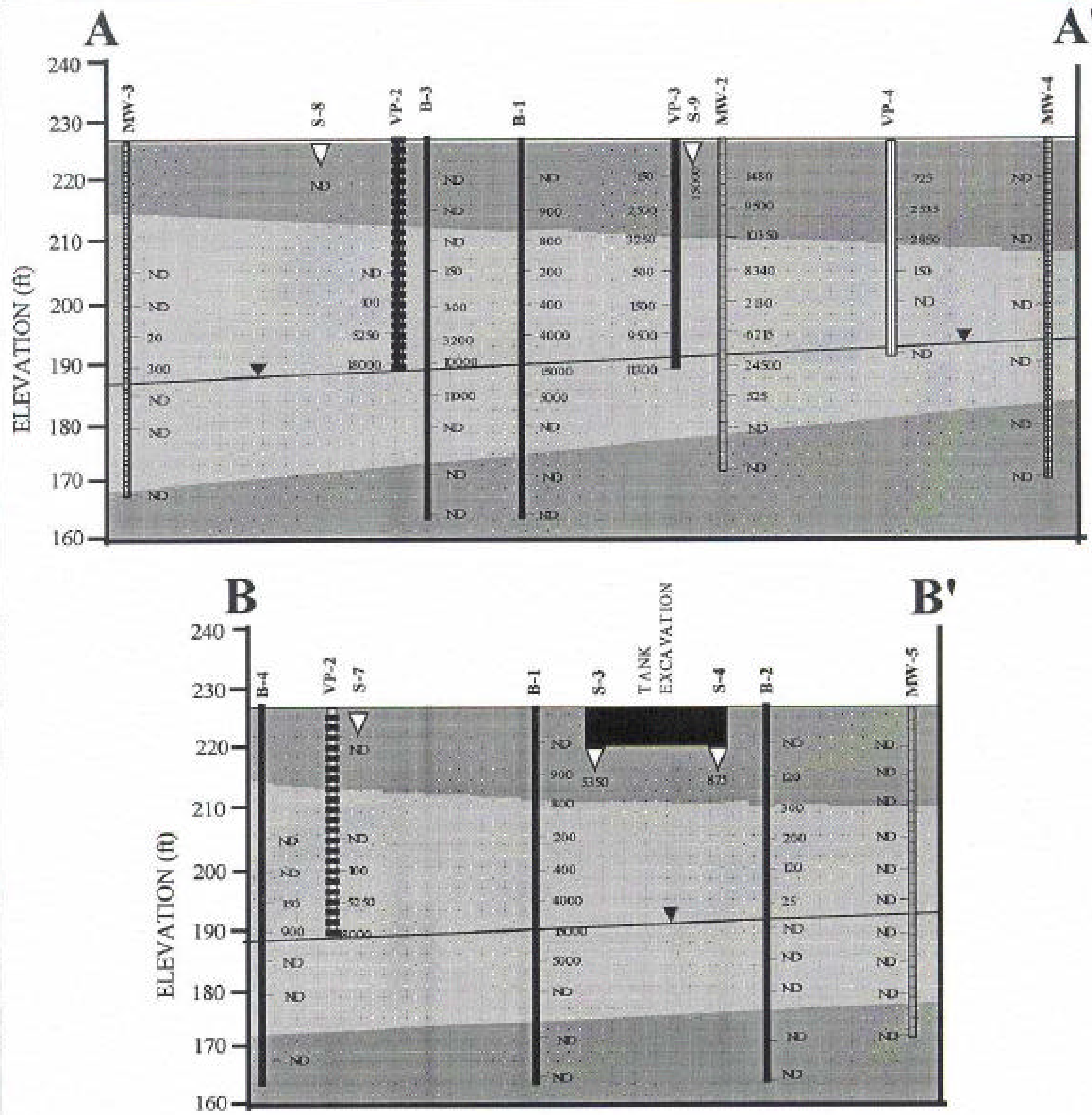
0 100 200

Date: June 4, 1995


1501
MARKET
ST
4ft Diameter Storm Drain
P
E
S
S
W
W
P
E
SITE UTILITIES MAP
FIGURE 3
LEGEND
Sewer manhole
Storm drain mahoe
Water line
Sewer line
Electric line
Phone line
Scale (feet)
0
20
40
Approximate location of Tank Excavation and Product Lines
Approximate location of Property Line
Date: June 4, 1995



MW-4
A'
B-5
1501
MARKET
ST
VP-4
VP-3
MW-2
S-9
B
B-4
S-7
VP-1
VP-2
B-1
S-1
S-2
S-3
S-4
B-2
S-8
B-3
S-5
S-6
MW-5
B'
MW-1
MW-3
A
MARKET ST
MAIN ST
SITE MAP
FIGURE 4
LEGEND
Excavation Samples
Boring
Monitoring Well
Vapor Extraction Well
Scale (feet)
0
20
40
Approximate location of Tank Excavation and Product Lines
Approximate location of Property Line
Date: June 4, 1995



GEOLOGIC CROSS-SECTION A-A' A ND B-B'
FIGURE 5

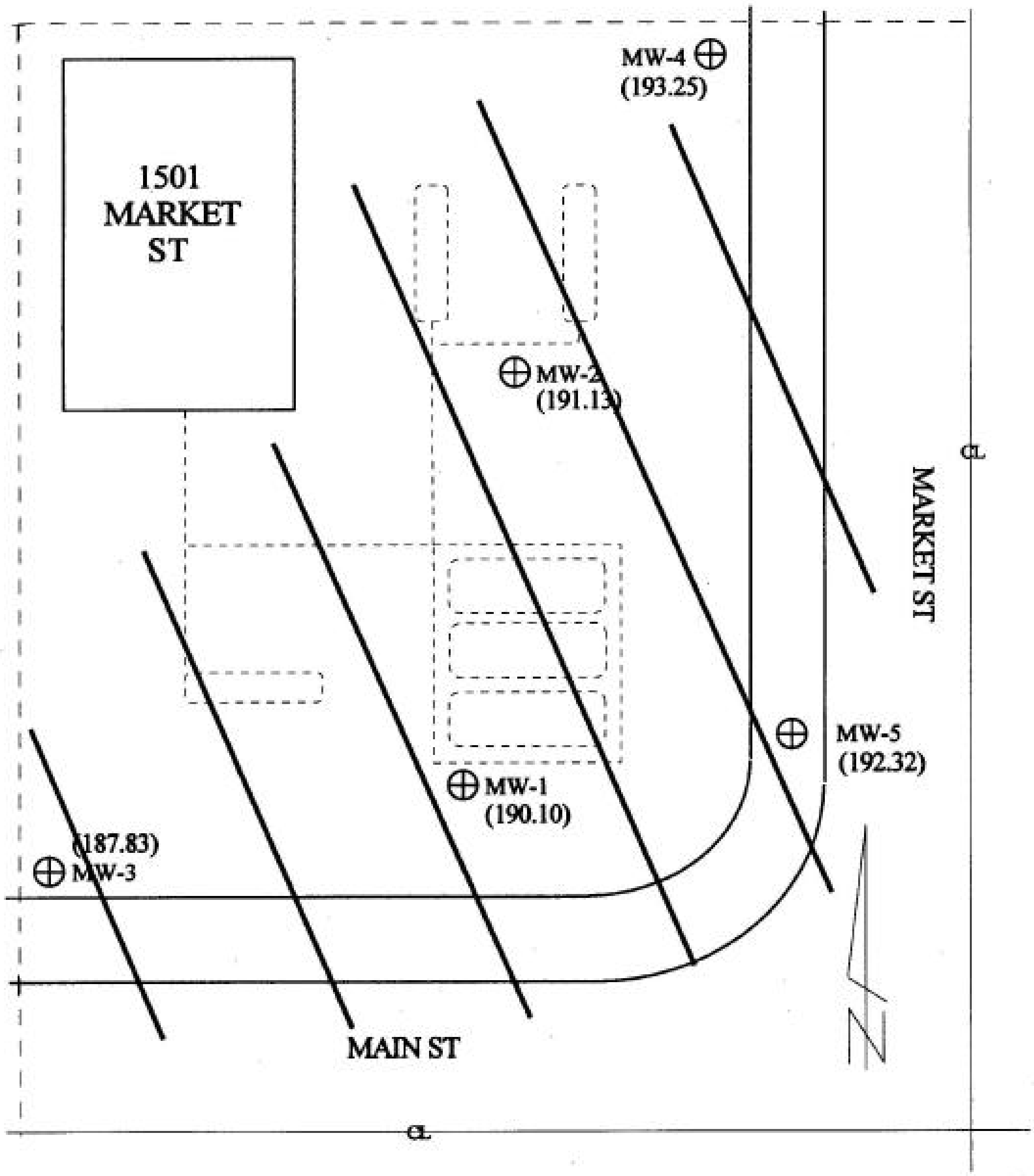
LEGEND

- ▽ Excavation Samples
- Boring
- Monitoring Well
- Vapor Extraction Well
- Silty fine sand (SP)
- Medium Sand (SM)

Horizontal Scale (feet)
0 20 40

1501 Market St.
AnyTown, CA

Date: June 4, 1995



GROUNDWATER GRADIENT -- March 23, 1995

FIGURE 6

LEGEND

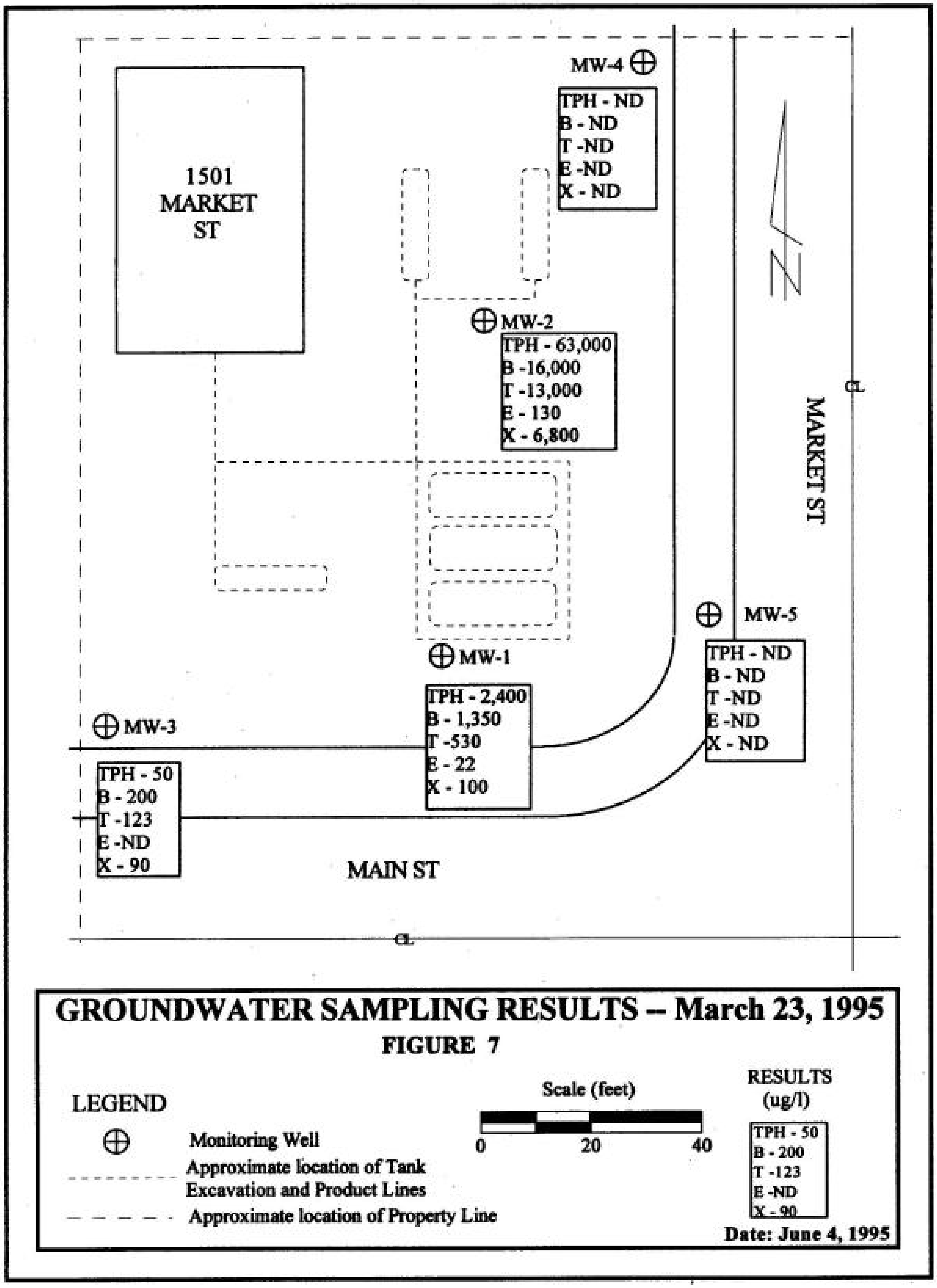
MW-1 Monitoring Well
(190.50) Groundwater Elevation

Approximate location of Tank Excavation and Product Lines

Approximate location of Property Line

Scale (feet) 0 20 40

Date: June 4, 1995



GROUNDWATER SAMPLING RESULTS -- March 23, 1995

FIGURE 7

Date: June 4, 1995

II. SAMPLE VAPOR PHASE RISK CALCULATIONS

EXAMPLES - VAPOR-PHASE MIGRATION AND RISK EVALUATION

The vapor-phase migration and risk evaluation are discussed in detail in Section 6. All the equations and tables referenced in this appendix can also be found in Section 6.

LEVEL 1 ANALYSIS

Site Description:

The site under evaluation is a neighborhood gasoline station that is surrounded by residential homes. This site experienced a release of gasoline from the underground storage tank system that was replaced in 1990. The site investigation identified the extent of soil contamination. Soil contamination extend off-site with soil contamination extending below a residential home that was built in the late 1960s. There were no impacts to groundwater at this site.

Due to the elevated levels of soil contamination in the area of the residence, a vapor phase evaluation was warranted. The following are typical steps that should be taken to do a Level 1 Evaluation of the potential health risk.

VAPOR TRANSPORT

Step 1 – Review of site data

A review of the site investigation data indicated that in the area of the residence the subsurface soils were primarily medium to coarse sands. Soil contamination extends from 15 to 25 feet (4.6 to 7.6 meters) below the residence at concentrations up to 2,500 mg/kg [Total Petroleum Hydrocarbons (TPH)].

Step 2 – Field verify site conditions

Initially the consultant visited the site and performed a detailed visual evaluation of the residence and its construction. This inspection identified the residence was a structure built with a concrete slab on-grade and the house was ventilated passively with only a forced air heating system. The concrete slab was inspected to verify its condition. Field observations identified the building slab as being in good condition with no observed deterioration or cracking. Based on these observations it was concluded that the use of the 0.01 slab attenuation factor was acceptable for use in the health risk evaluation. Additionally, the residence had an interior room height of 8 feet (2.44 meters).

Step 3 – Calculation of soil gas concentration

Since TPH soil concentrations exceed 100 mg/kg the appropriate method to calculate the level of benzene in soils gas is using Equation 6-13 presented below:

$$C_{sg} = \frac{VP * MW * MF}{R * T}$$

Where:
C_{sg} = the contaminant concentration in the soil vapor (mg/m^3)
VP = the contaminant vapor pressure at STP (atm)
MW = the molecular weight of the compound of concern (mg/mole)
MF = the mole fraction (dimensionless)
R = the universal gas constant (atm-m^3/mole-K)
T = the temperature in degrees Kelvin (Standard temperature of 293°K)

Using the default values presented in Table 6-4 the soil gas concentration is calculated as follows.

$$C_{sg} = \frac{0.13 \text{ atm} * 78{,}110 \text{ mg/kg} * 0.03}{0.000082 \text{ atm-m}^3\text{/mole-°K} * 293 \text{ °K}} = 12{,}700 \text{ mg/m}^3$$

Step 4 – Calculate Effective Diffusion Coefficient

To calculate the effective diffusion coefficient Equation 6-17, presented below, is used.

$$D_e = \frac{D_a * \theta_a^{3.33}}{\theta^2}$$

Where:
D_e = the effective air diffusion coefficient (cm^2/sec)
D_a = the diffusion coefficient of compound in air (cm^2/sec)
θ_a = the air filled porosity (dimensionless)
θ = the total soil porosity (dimensionless)

Since the soils identified in the area of concern (medium to coarse sands) have not been tested to determine the soils porosity and moisture content the default values for porosity and air filled porosity were used (Table 6-4). In reviewing Table 6-3

$$D_e = \frac{0.088 \text{ cm}^2\text{/sec} * 0.20^{3.33}}{0.30^2} = 0.0046 \text{ cm}^2\text{/sec}$$

Step 5 – Calculate Vapor Flux

To calculate vapor flux Equation 6-16 presented below is used.

$$Fx = \frac{D_e * C_{sg} * 3{,}600 \text{ sec/ hr}}{X * 10{,}000 \text{ cm}^2\text{/m}^2}$$

Where:
Fx = the contaminant vapor flux (mg/hr-m^2)
D_e = the effective air diffusion coefficient (cm^2/sec)
C_{sg} = the contaminant concentration in the soil vapor (mg/m^3)
X = the depth or distance to contamination in the vadose zone (m)

$$Fx = \frac{0.0046 \text{ cm}^2\text{/sec} * 12{,}700 \text{ mg/m}^3 * 3{,}600 \text{ sec/ hr}}{4.6 \text{ m} * 10{,}000 \text{ cm}^2\text{/m}^2} = 4.56 \text{ mg/hr-m}^2$$

Step 6 – Calculation of Indoor Air Concentration

To calculate the indoor air concentration Equation 6-18 presented below is used.

$$C_i = \frac{S_b * F_x * A}{V * E} = \frac{S_b * F_x}{R_h * E}$$

Where:

C_i	=	the indoor air concentration (mg/m^3)
S_b	=	the slab attenuation factor (dimensionless)
F_x	=	the contaminant vapor flux (mg/hr-m^2)
A	=	the room floor area (m^2)
V	=	the room volume (m^3)
E	=	the indoor air exchange rate per hour (hr^{-1})
R_h	=	the room height (m)

$$C_i = \frac{0.01 * 4.56 \text{ mg/hr-m}^2}{2.44 \text{ m} * 0.5 \text{ hr}^{-1}} = 0.0374 \text{ mg/m}^3$$

VAPOR RISK

Steps 1 though 6 have calculated the indoor air concentration in overlaying residence. This is the vapor transport portion of the evaluation. This indoor air concentration, 0.0374 mg/m^3, is the air concentration that the occupants are exposed to through inhalation. The following steps calculate the human exposure and the potential health risk to these individuals. Since in this evaluation we are evaluating residential exposure then the default values for health risk exposure (Table 6-9) need to be used.

Step 7 – Calculating Human Exposure

To calculate human exposure through inhalation Equation 6-23, presented below, is used

$$IT = \frac{C_i * IR * ET * EF * ED}{BW * AT}$$

Where:

IT	=	the chemical intake (mg/kg-day)
C_i	=	the indoor air concentration (mg/m^3)
IR	=	the inhalation rate (m^3/day)
ET	=	the exposure time (hr/24hr)
EF	=	the exposure frequency (days/yr)
ED	=	the exposure duration (yr)
BW	=	the body weight (kg)
AT	=	the averaging time (days)

$$IT = \frac{0.0374 \text{ mg/m}^3 * 20 \text{ m}^3\text{/day} * 24\text{hr/24hr} * 365 \text{ days/yr} * 70 \text{ yr}}{70 \text{ kg} * 25500 \text{ days}} = 0.0107 \text{ mg/kg-day}$$

Step 8 – Calculation of Carcinogenic Risk

To calculate the carcinogenic risk Equation 6-24, presented below, is used.

Risk = IT * SF

Where: Risk = the estimate of health risk (dimensionless)
IT = the chemical intake (mg/kg-day)
SF = the contaminant carcinogenic slope factor ($[mg/kg\text{-}day]^{-1}$)

Risk = 0.0107 mg/kg-day * 0.1 $[mg/kg\text{-}day]^{-1}$ = 1.07×10^{-3}

Based on this analysis, the incremental cancer risk is the inverse of the risk calculated above. This result indicates that there is a cancer risk of one in a population of 934 people. This result represents an unacceptable health risk. The acceptable level or risk is one in a population of 1,000,000 (one in a million).

Based on this result, the responsible party should either proceed with remediation or complete a higher level of investigation to collect site-specific information to support a Level 2 risk evaluation.

LEVEL 2 ANALYSIS

Site Description:

The site under evaluation is a commercial property that historically was operated as a Dry Cleaning business. Site investigation has identified soil contamination beneath the concrete floor slab in the area of the former dry cleaning equipment. The investigation identified only Tetrachloroentne (PCE) at a maximum concentration of 10 mg/kg approximately 1 foot below the floor slab.

Due to the elevated levels of soil contamination, a vapor phase evaluation was warranted. The following are typical steps that should be taken to do a Level 1 Evaluation of the potential health risk.

<u>VAPOR TRANSPORT</u>

Step 1 – Review of site data

A review of the site investigation data indicated that the maximum soil concentration was 10 mg/kg at 1 foot below (0.33 meters) the floor slab. During the site investigation the soils at the site were identified as Lindavista Formation derived fill soils consisting of silty fine sands. Due to fine grained nature of the fill soils the consultant obtained samples and has site-specific physical testing done to determined the in situ soil porosity, moisture content and the soils organic carbon content.

This additional testing provided the following physical properties:

Bulk density	1.9 gm/cm^3
Total porosity	0.255 dimensionless
Water filled porosity	0.135 dimensionless
Air filled porosity	0.120 dimensionless
Total organic carbon content	0.01 dimensionless

Step 2 – Field verify site conditions

Additionally the consultant performed a detailed visual evaluation of the commercial space under consideration, in addition to the adjacent units, to evaluate the building construction and current condition. This inspection identified the structure was built with a concrete slab on-grade within the past 10 years and the commercial unit was designed with a ventilation system that provided 1.0 air exchange per hour with the outside air.

The concrete slab was inspected to verify its condition. Field observations identified the building slab as being in good condition with not observed deterioration or cracking. Based on these observations it was concluded that the use of the 0.01 slab attenuation factor was acceptable for use in the health risk evaluation. Additionally, the commercial space had a ceiling height of 8 feet (2.44 meters).

Step 3 – Calculation of soil gas concentration

Based on the site investigation the maximum soil concentration identified was 10 mg/kg. The chemical properties of PCE are listed in Table 6.2a. At the levels of residual soil contamination Equation 6-14 presented below, should be used:

$$C_{sg} = \frac{H * C_s * \rho_b}{\theta_w + (K_d * \rho_b) + (H * \theta_a)} * (1 \times 10^{-3}\ kg/gm) * (1 \times 10^{6}\ cm^3/m^3)$$

Where:

C_{sg} = the contaminant concentration in the soil vapor (mg/m^3)
H = the Henrys Law constant (dimensionless)
C_s = the concentration of compound in soil (mg/kg)
ρ_b = the dry bulk density of soil (gm/cm^3)
K_d = the soil/water distribution coefficient (cm^3/gm)
= $(K_{oc} * f_{oc})$
K_{oc} = the organic carbon partitioning coefficient (cm^3/gm)
f_{oc} = the weight fraction of organic carbon in soil (dimensionless)
= TOC/10,000
θ_a = the air filled porosity (dimensionless)
θ_w = the water filled porosity (dimensionless)

$$C_{sg} = \frac{0.75 * 1.0\ mg/kg * 1.8\ gm/cm^3}{(0.135 + (270\ cm3/gm * 0.01) * 1.8\ gm/cm^3) + (0.75 * 0.120)} * (1 \times 10^{3}\ kg\text{-}\ cm^3/gm\text{-}\ m^3)$$

$$C_{sg} = 265\ mg/m^3$$

Step 4 – Calculate Effective Diffusion Coefficient

To calculate the effective diffusion coefficient Equation 6-17, presented below, is used.

$$D_e = \frac{D_a * \theta_a^{3.33}}{\theta^2}$$

Where:

D_e = the effective air diffusion coefficient (cm^2/sec)
D_a = the diffusion coefficient of compound in air (cm^2/sec)
θ_a = the air filled porosity (dimensionless)
θ = the total soil porosity (dimensionless)

Since the soils were tested the site-specific values presented in Step 1 are used along with the diffusion coefficient obtained from Table 6-2a.

$$D_e = \frac{0.072\ cm^2/sec * 0.120^{3.33}}{0.255^2} = 0.00095\ cm^2/sec$$

Step 5 – Calculate Vapor Flux

To calculate vapor flux Equation 6-16 presented below is used.

$$Fx = \frac{D_e * C_{sg} * 3{,}600 \text{ sec/ hr}}{X * 10{,}000 \text{ cm}^2/\text{m}^2}$$

Where:
- Fx = the contaminant vapor flux (mg/hr-m^2)
- D_e = the effective air diffusion coefficient (cm^2/sec)
- C_{sg} = the contaminant concentration in the soil vapor (mg/m^3)
- X = the depth or distance to contamination in the vadose zone (m)

$$Fx = \frac{0.00095 \text{ cm}^2/\text{sec} * 265 \text{ mg/m}^3 * 3{,}600 \text{ sec/ hr}}{0.33 \text{ m} * 10{,}000 \text{ cm}^2/\text{m}^2} = 0.275 \text{ mg/hr-m}^2$$

Step 6 – Calculation of Indoor Air Concentration

To calculate the indoor air concentration Equation 6-18 presented below is used.

$$C_i = \frac{S_b * F_x * A}{V * E} = \frac{S_b * F_x}{R_h * E}$$

Where:
- C_i = the indoor air concentration (mg/m^3)
- S_b = the slab attenuation factor (dimensionless)
- F_x = the contaminant vapor flux (mg/hr-m^2)
- A = the room floor area (m^2)
- V = the room volume (m^3)
- E = the indoor air exchange rate per hour (hr^{-1})
- R_h = the room height (m)

$$C_i = \frac{0.01 * 0.275 \text{ mg/hr-m}^2}{2.44 \text{ m} * 1 \text{ hr}^{-1}} = 0.00113 \text{ mg/m}^3$$

VAPOR RISK

Steps 1 though 6 have calculated the indoor air concentration in overlaying commercial space. This is the vapor transport portion of the evaluation. This indoor air concentration, 0.000113 mg/m^3, is the air concentration that the occupants are exposed to through inhalation. The following steps calculate the human exposure and the potential health risk to these individuals. Since in this evaluation we are evaluating commercial exposure, then the default values for health risk exposure (Table 6-9) need to be used.

Step 7 – Calculating Human Exposure

To calculate human exposure through inhalation Equation 6-23, presented below, is used

$$IT = \frac{C_i * IR * ET * EF * ED}{BW * AT}$$

Where:
- IT = the chemical intake (mg/kg-day)
- C_i = the indoor air concentration (mg/m^3)
- IR = the inhalation rate (m^3/day)
- ET = the exposure time (hr/24hr)
- EF = the exposure frequency (days/yr)
- ED = the exposure duration (yr)
- BW = the body weight (kg)
- AT = the averaging time (days)

$$IT = \frac{0.00113 \text{ mg/m}^3 * 20 \text{ m}^3\text{/day} * 12\text{hr/24hr} * 250 \text{ days/yr} * 25 \text{ yr}}{70 \text{ kg} * 25500 \text{ days}}$$

$$IT = 3.94 \times 10^{-5} \text{ mg/kg-day}$$

Step 8 – Calculation of Carcinogenic Risk

To calculate the carcinogenic risk Equation 6-24, presented below, is used. The slope factor for PCE is presented in Table 6-1.

$$Risk = IT * SF$$

Where:
- $Risk$ = the estimate of health risk (dimensionless)
- IT = the chemical intake (mg/kg-day)
- SF = the contaminant carcinogenic slope factor ($[\text{mg/kg-day}]^{-1}$)

$$Risk = 3.94 \times 10^{-5} \text{ mg/kg-day} * 2.10 \times 10^{-2} [\text{mg/kg-day}]^{-1} = 8.28 \times 10^{-7}$$

Based on this analysis, the incremental cancer risk is the inverse of the risk calculated above. This result indicates that there is a cancer risk of one in a population of 1,209,190 people. This result represents an unacceptable health risk. The acceptable level or risk is one in a population of 1,000,000 (one in a million).